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INFLUENCE OF TRANSVERSE MAGNETIC FIELD ON EMISSION POWER AND POLARIZATION OF HELIUM-NEON LASER ON WAVELENGTH $\lambda = 3.39\ \mu$

by

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NOTICE

INFLUENCE OF TRANSVERSE MAGNETIC F‾ LD ON EM‾SSION POWER AND POLARIZATION OF HELIUM-NEON LASER ON WAVELENGTH $\lambda = 3.39\ \mu$

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The effect of transverse and longitudinal magnetic fields on the emission power of the helium-neon laser on the wavelengths $\lambda = 0.63\ \mu$ and $\lambda = 1.15\ \mu$ has been more thoroughly investigated in recently published research [1-5]. The effect of the magnetic field on emission on the wavelength $\lambda = 3.39\ \mu$ has practically been ignored. Only one work pertaining to this question [6] can be cited, and in this particular work basic attention was devoted to the effect of strong magnetic fields (up to 2,000 e). Nevertheless it was found that the effect of the transverse magnetic field is strongest at intensities up to 150 e. The results obtained [6] pertain to one mode of perturbation (HF) and are of a qualitative character.

The purpose of the present work was to investigate in greater detail the effect of a weak transverse magnetic field on the output power and polarization of the helium-neon laser, operating on the wavelength $\lambda = 3.39\ \mu$ at various pump capacities. Basic attention was devoted to the behavior of the π- and σ-components of the emission, since all theoretical works [5, 7] dealing with the investigation of the effe t of the magnetic field examine emission consisting of these components, whereas in the above cited experimental works the effect of a magnetic field on the total power of emission was investigated. At the same time the dependence of emission polarization in the presence of a magnetic field on change in resonator quality was investigated for the π- and σ-components. Both the absolute value of the qualities and the sign of the difference between them changed. The influence of quality on emission polarization in the presence of a magnetic field de‾ives from theoretical examination of the problem, but there have not yet been any indications of its presence in experimental works.

Emission of the helium-neon laser on the wavelength $\lambda = 3.39\ \mu$ has several features in comparison with other transitions in neon. First of all the $3S_2$-$3P_4$ transition, corresponding to this wavelength, has a large gain (up to 23 db/m [8]) and relatively narrow Doppler contour (of the order of 300 MHz). The former has the result that low-quality resonators can be used, while the latter practically permits generation in one or two axial modes.

The intensity of the magnetic field used in this work changed smoothly from 0 to 200 e. It should be pointed out here that these intensities correspond to weak magnetic fields. Therefore during investigation of the effect of such a field one cannot expect any significant plasma effects [3], which would greatly simplify analysis of the experimental data obtained, since in this case much importance is attached to effects related to the Zeeman separation of the levels of the active substance.

The transverse magnetic field was created by means of two flat coils, between which was placed the laser tube. Nonuniformity of the field was not worse than 3% through the entire length of the discharge gap. In order to reduce the effect of scatter fields, the laser and the coils were mounted on a nonmagnetic base. The intensity of the magnetic field was 13.5 e/a. The laser was stimulated by direct current and had a glass tube with a discharge gap l = 85 cm, inside diameter d = 7 mm, and quartz windows, arranged at Brewster's angle. The tube was filled with a helium-neon mixture with partial pressure ratio $P_{Ne}:P_{He}$ = 1:6 with a total pressure of 1.2 torr. For generation, the tube was placed in a resonator, the quality of which was varied by means of mirrors with different reflection coefficients. As is known, when an atom is placed in the magnetic field H, the atomic level characterized by the quantum number of total moment I is separated into 2I + 1 sublevels, which have different magnetic quantum numbers m. The selection rules resolve such transitions between sublevels of the upper and lower states, in which the magnetic quantum number does not change (π-component) or changes by ± 1 (σ-component). Hence these components have different polarizations. One (the π-component) is polarized linearly along the field, while the other (the σ-component) is polarized circularly. Since the output emission is recorded perpendicular to the magnetic field, these components are seen as two emissions with mutually perpendicular linear polarizations. Because of the Brewster windows, the insertion losses of these components are not the same, and this results in variation in the qualities of the resonator in mutually perpendicular directions. Thus it is necessary to take into account two qualities Q_π and Q_σ. Three resonators were used in this work: the first had qualities Q_π and Q_σ of $1.7 \cdot 10^6$ and $3.3 \cdot 10^6$ respectively (mirrors with coefficient of reflection 50%); the second -- $2.5 \cdot 10^6$ and $6.5 \cdot 10^6$ (mirrors with coefficients of reflection 50 and 98%); the third -- $7.0 \cdot 10^6$ and $40 \cdot 10^6$ (mirrors with coefficient of reflection 98%). This corresponded to the I position of the tube in relation to the

magnetic field, i.e., the magnetic field was normal to the polarization plane in the null magnetic field. Another tube position was also investigated in the work: the magnetic field was parallel to the polarization plane in the null magnetic field. In this case the qualities for the Q_π and Q_σ components changed places (tube position II), which corresponds to a change in the sign of the quality difference. The distance between the mirrors was 123 cm. Adjustment was accomplished at maximum output power in the absence of a magnetic field.

The output emission, premodulated by 2,000 Hz, was focused by means of a quartz lens on the target area of an uncooled InAs photoelement, in front of which was placed an IR filter. The photo receiver output was switched to a 28-IM measurement amplifier. The polarization of the emission was determined by means of an analyzer consisting of two silicon plates, arranged at Brewster's angle. The measurement indicated that the degree of polarization of the analyzer was 95%.

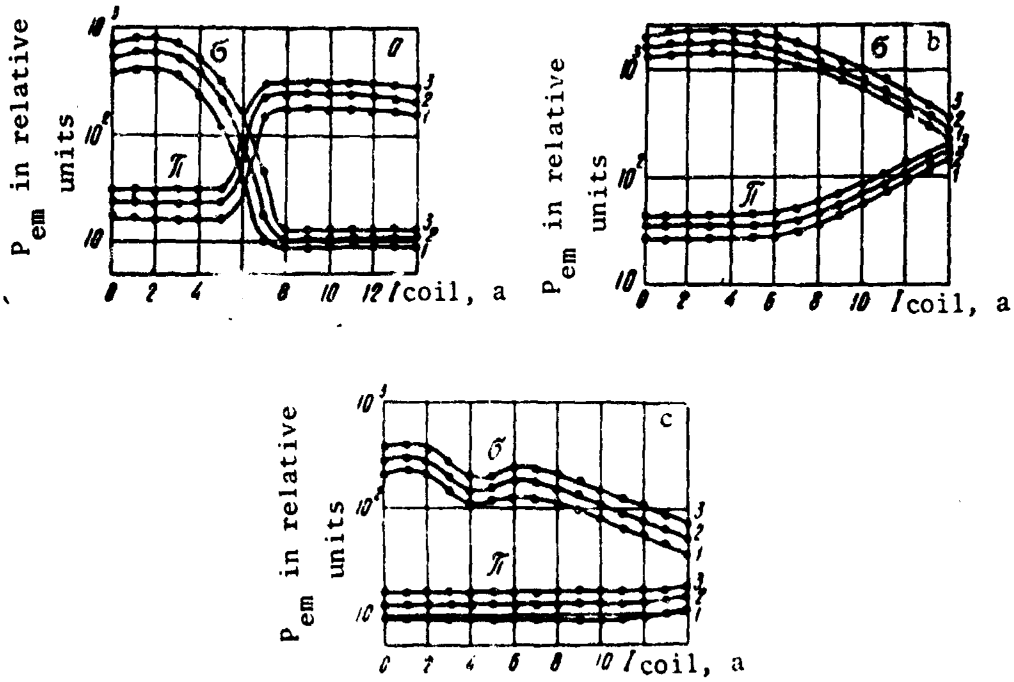

Figure 1. Emission power of π- and σ-components ($\lambda = 3.39\ \mu$) as function of transverse magnetic field (1a = 13.5 e) at various feed powers and various resonator qualities. Position I -- magnetic field perpendicular to direction of polarization in null magnetic field. a) $Q_\sigma = 3.3\cdot10^6$; $Q_\pi = 1.7\cdot10^6$; b) $Q_\sigma = 6.5\cdot10^6$; $Q_\pi = 2.5\cdot10^6$; c) $Q_\sigma = 40\cdot10^6$; $Q_\pi = 7\cdot10^6$. DC power source: 1, $I_p = 25$ ma; 2, $I_p = 35$ ma; 3, $I_p = 45$ ma.

During the experiment the dependence of the emission power of the laser and its polarization on the transverse magnetic field was recorded at various feed currents. The discharge current was maintained constant as the magnetic field was changed. The dependence of emission power on the orientation of the tube in relation to the magnetic field was revealed. The results of the measurements are represented in the figures. Figure 1 corresponds to position I of the tube, and Figure 2, to position II. One graph is presented for position II of the tube, since the graphs for the other two pairs of qualities in this position are analogous. The emission power of the π- and σ-components are plotted on the ordinate axis in relative units (readings of the 28-IM instrument), and the current in the coils is plotted on the abscissa in amperes. As seen in Figure 1, in weak magnetic fields only the σ-component is stimulated, since the quality for it is greater than for the π-component. Because of the competition, the π-component is not stimulated (a certain level of the π-component on the figures is attributed to analyzer imperfection. As seen in the figures, this level does not exceed 5% of the level of the σ-component, which is in agreement with the 95% degree of polarization of the analyzer). As the magnetic field is intensified further, the power of the σ-component should drop (Figure 1a). This is explained by the fact that when the magnetic field is applied, the σ-component will have two independent Doppler expanded amplification lines, displaced in the opposite directions when the field is intensified in relation to the central frequency, on which one axial mode is generated. At the same time, the power of the π-component begins to increase, since the diminishing σ-component suppresses it less and less. As soon as generation of the σ-component is terminated (Figure 1a), the generation power of the π-component reaches a level determined by the quality of the resonator for this component, and does not change beyond this point, since the amplification lines of this component, as the field is intensified, remain constant in relation to the axial resonator, on which generation occurs. Regeneration of the σ-component in adjacent axial modes is suppressed by the π-component. A change in resonator quality has a great effect on these dependences. An increase in quality is accompanied by expansion of the range of magnetic field intensity in which generation of the σ-component is possible, which is determined by the increase in the height of the Doppler contour above the generation threshold. When Q_σ is large (Figure 1c), generatic of the σ-component is possible in adjacent axial modes -- small peak at 80 e, which corresponds to 120 MHz Zeeman separation (the distance between the axial modes in the generator used is $C/2L = 120$ MHz). In the case of position II of the tube only the π-component is generated, the power of which remains practically constant. The former is explained by the fact that Q_π is greater than Q_σ and generation of the σ-component is suppressed, and the latter by the fact that the line of amplification of the π-component is not displaced in the magnetic field in relation to axial resonance.

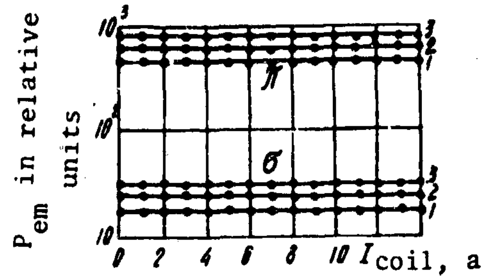

Figure 2. Emission power of π- and σ-components (λ = = 3.39 μ) as function of transverse magnetic field (1a = 13.5 e) at various feed powers. Position II, magnetic field parallel to direction of polarization in null magnetic field. $Q_\pi = 3.3 \cdot 10^6$; $Q_\sigma = 1.7 \cdot 10^6$.

Direct current feed: 1, I_p = 25 ma; 2, I_p = 35 ma; 3, I_p = 45 ma.

Thus it was found that when the Q factors are small there exists a small range of magnetic field intensity in which the π- and σ-components can exist simultaneously. In this case it is interesting to trace the change in emission polarization as the magnetic field is changed. In weak fields (up to 65 e) polarization remains linear and is determined by Brewster's windows. Emission eventually becomes elliptically polarized and the degree of ellipticity decreases as the intensity of the transverse magnetic field increases until emission is no longer polarized circularly. After that the emission again becomes elliptically polarized, whereupon the ellipse is rotated 90° in relation to the initial ellipse, and the degree of ellipticity increases with further intensification of the magnetic field with the conversion of emission into linearly polarized emission, where the direction of polarization is perpendicular to that determined by the Brewster windows.

The results presented in this work are in qualitative agreement with the theoretical conclusions of previous works [5, 7], although these conclusions are not entirely applicable to the operation of the laser on the wavelength λ = 3.39 μ, since the assumptions used in these works concerning the relations of the Doppler width of the amplification line and the natural width ($\Delta\nu_D \gg \gamma$) do not completely approach the transition corresponding to wavelength λ = 3.39 μ, which has a rather narrow Doppler contour.

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13. ABSTRACT

The dependence of emission power and polarization of the helium-neon laser on transverse magnetic field and with change in resonator quality is investigated. The possibility of emission with circular polarization in a laser with Brewster windows has been established.

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